# Relative Dating: Telling Time Using Fossils

*Teachers: This lesson contains two activities with discussion questions related to the AFG video clips about fossils and geologic time. These parts may be used individually or together, depending on the needs of your class and your time constraints.*

*Note: You can access and view the video clips used in this lesson in the Teacher resources section of the AFG website (www.pbs.org/americanfieldguide/teachers).*

**Grade Level: 7-9**

**Background**

The geologic timescale is based on the history of life on our planet. Eras, epochs, and periods all relate to the changes in Earth's biology. Early geologists noticed that certain species, families, or even phyla disappear completely or appear in the rock record. The most famous example of this is the dinosaurs that appeared during the Triassic and disappeared at the end of the Cretaceous. The era that the dinosaurs existed in was the Mesozoic meaning middle life. After the dinosaurs went extinct, mammals expanded and became the predominant group of land animals. The time of the mammals is called the Cenozoic, or new life.

Until recently, there was no way to determine how old the rock units actually were. Thus determining the age of rocks was done using relativity. For instance, dinosaurs came and went before large mammals. This can be determined by studying the relationships between rock units. Worldwide, rock units that bear dinosaur bones are underneath those that bear mammal bones. According to the principle of superposition, they must be older. Thus, a geologist finding two widely separated rock units, one containing mammal bones and one containing dinosaur bones, knows that the unit with dinosaurs is older than the one with the mammals. This is called **relative dating.** It wasn't until the discovery of radioactivity in rocks that geologists were able to give rocks **absolute ages** (for example: dinosaurs went extinct 66 million years ago). Relative dating is cheaper and easier and so is regularly used by geologists for most purposes.

Fossil range charts can show the length of time that various organisms have been found in the fossil record. For instance, the range of dinosaurs is from the beginning of the Triassic to the end of the Cretaceous. This is usually represented in a bar graph form with either the x or y axis representing time and the other axis representing the fossil groups present. Geologists use the x-axis for time because it correlates with our conception of time having a starting point and marching towards our current position. The y-axis also works in geology because rock units are vertically stacked. Thus older times are placed at the bottom of the y-axis and time gets younger as it marches up the y-axis. By determining which fossils are present in a given rock sample, the relative age of the rock can be determined. Using individual species, geologists can narrow down the age of a rock, often to within a million years (a small amount of time for geologists).

In this activity, students will use fossil range charts to help them understand the concept of relative dating. An optional teacher-directed activity will help students learn about fossil range charts. Then they will graph a range chart for ammonites, a marine group of organisms that looked like nautilus's and went extinct at the same time as the dinosaurs. They will then use the range chart to determine the geologic age for several 'rocks' and will determine which rocks will be most useful for oil companies looking to drill for oil.

**Related National Standards**

This lesson addresses the following National Content Standards found at:
http://books.nap.edu/html/nses

Content Standard C: As a result of their activities in grades 5-8, all students should develop understanding of

- Diversity and Adaptations of Organisms
    - Extinction of a species occurs when the environment changes and the adaptive characteristics of a species are insufficient to allow its survival. Fossils indicate that many organisms that lived long ago are extinct. Extinction of species is common; most of the species that have lived on the earth no longer exist.

Content Standard C: As a result of their activities in grades 9-12, all students should develop understanding of

- Biological Evolution
    - Species evolve over time. Evolution is the consequence of the interactions of (1) the potential for a species to increase its numbers, (2) The genetic variability of offspring due to mutation and recombination of genes, (3) a finite supply of the resources required for life, and (4) the ensuing selection by the environment of those offspring better able to survive and leave offspring.
    - Natural Selection and its evolutionary consequences provide a scientific explanation for the fossil record of ancient life forms.

Content Standard D: As a result of their activities in grades 5-8, all students should develop understanding of

- Earth's history
    - Fossils provide important evidence of how life and environmental conditions have changed.

Content Standard D: As a result of their activities in grades 9-12, all students should develop understanding of

- The Origin and Evolution of the Earth System
    - Geologic time can be estimated by observing rock sequences and using fossils to correlate the sequences at various locations. Current methods include using the known decay rates of radioactive isotopes present in rocks to measure the time the rock was formed.

**Extension Websites from PBS**

- **A Science Odyssey- The Dating Game**
  http://www.pbs.org/wgbh/aso/resources/guide/earthact4index.html
  Use this website for a lesson on absolute dating using radioactive elements.
- **Newtons Apple- Dinosaur 1 and 2**
  http://www.pbs.org/ktca/newtons/9/dino1.html
  http://www.pbs.org/ktca/newtons/9/dino2.html
  These sites contain a variety of activities related to dinosaur fossils.
- **Nova Teachers Guide-The Curse of T. Rex**
  http://www.pbs.org/wgbh/nova/trex/
  This Nova program will allow students to see a real paleontological dig and to consider ethical and moral implications of commercial fossil collecting.

**Acknowledgement**

Thanks to Dr Tim Palmer C.Geol., F.G.S., Executive Officer, The Palaeontological Association for his help with the palaeontological information for this activity.

## Activity 1: I Always Knew My Teacher Was a Dinosaur!

**Time allotted:**
20 minutes

**Materials:**
Overhead transparency or poster prepared as described below

**Objectives:**
- Students will learn to read fossil range charts.
- Students will develop an understanding of the strengths and weaknesses of the fossil record.
- Students will become familiar with the concepts index fossil and fossil range.

Before watching the first video, introduce the concepts of relative dating vs. absolute dating (see background above).


**Watch the AVG Video Segment: "Fossil Museum"**
Start the video at 'More than 300 million years ago' and stop after hearing 'Indiana was once located in the tropics'

*Note: You can access and view the video clips used in this lesson in the Teacher Resources section of the AFG Web site (www.pbs.org/americanfieldguide/teachers).*

**Discussion Questions for Video Segment**
- Describe some information that fossils can give about the past.
- What examples of relative ages did you hear? Absolute age?

**Teacher Instructions**
- Make your own 'fossil' range-chart to illustrate how they work to your students! I have done this activity using different groups of people such as basketball players from the University of North Carolina Basketball team and teachers from my school. Any population that your students knows fairly well will work.
- Choose a group of people, for example, teachers in your school. You will want about 10 individuals, some of who have been around for a long time and some of whom only were there for one or two years. Make a bar graph with time on the X-axis and teachers names on the Y-axis. Shade the years that correspond with each teacher's tenure at the school. Now make your graph into an overhead (or into a power point slide) to share with the class.
- Tell students to imagine that there has been a fire in the library (or that a mouse has munched on the yearbooks or some other calamity has occurred). The librarian is trying to reconstruct what's left of the yearbooks and has come upon a pile of pages with photographs on them. Show the students your range chart. Have them describe what they can tell by looking at it.

| name | 81 | 82 | 83 | 84 | 85 | 86 | 87 | 88 | 89 | 90 | 91 | 92 | 93 | 94 | 95 | 96 | 97 | 98 | 99 | 00 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Mr. X | | | | | | | | | | | | | | | | | | | | |
| Ms Y | | | | | | | | | | | | | | | | | | | | |
| Mrs. Z | | | | | | | | | | | | | | | | | | | | |
| Miss Q | | | | | | | | | | | | | | | | | | | | |

Figure 1: A sample fossil range chart for teachers in a school.

**Discussion Questions**

- If you find a photo that has Mr. X, Ms Y, and Mrs. Z in it, what year is it from? How do you know? (Be sure that X, Y, and Z were all there together for only one year. This question illustrates the idea of overlapping ranges.)
- If you find a photo that has Mr. X, Ms Y, and Miss Q., what year is it from? How do you know? (Assuming Miss Q. has been there for only a year or so, this question illustrates the idea of an index fossil)
- If you find a photo that has Mr. X, Ms Y, but not Mrs. Z in it, what year is it from? Does the fact that Mrs. Z is missing mean anything? (no, not all fossils are found in all rocks.)
- Teachers: my charts usually end up having more index fossils toward the recent end of the chart because I wasn't around 20 years ago and the people who were don't remember the short-timers. If yours came out the same way, ask the students why they think that happened. Help them discuss that the fossil record is similar. Short-lived species that didn't preserve well or that existed only in small regions often aren't fossilized in large numbers (if at all) and therefore are overlooked by paleontologists. Thus the life appears more diverse in more recent epochs leading to the concept of an evolutionary tree, but this is merely an artifact of preservation.

## Activity 2: Oil Exploration and Fossil Ranges

**Time allotted:**
45 minutes (can be completed as homework)

**Materials:**
- Copies of the student instructions (attached)
- Optional: fossils, particularly fossil ammonites, belemnites, orthocones, or nautilus

**Objectives:**
- Students will learn to use bar graphs to plot fossil ranges.
- Students will develop an understanding of 'relative time' using fossil range charts.
- Students will use fossil range charts to understand how a rock can be dated using the geologic timescale.
- Students will use fossil range charts to predict where oil might be found.


**Watch the AVG Video Segment: "Iowa's Geology- Fossils, Sediments and Loess"**
Start at 'The interesting sequence of sedimentary rocks…' and stop after hearing 'all hidden by layers of clay and topsoil'.

*Note: You can access and view the video clips used in this lesson in the Teacher Resources section of the AFG Web site (www.pbs.org/americanfieldguide/teachers).*

**Discussion Questions for Video Segment:**
- If you were a geologist in the field looking at the various layers of Iowa's Geology, how would you know which layers are the oldest? (principal of Original Horizontality and Principal of Superposition)
- How do these concepts relate to the fossil record and fossil range charts?

**Have students complete Activity 2 (see student directions).**

**Assessment for Student Activity**

Sample of fossil range chart

| Cephalopod Order | Cambrian | Ordovician | Silurian | Devonian | Mississippian | Pennsylvanian | Permian | Triassic | Jurassic | Cretaceous | Tertiary | Quaternary |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Goniatites | | | | | ■ | ■ | | | | | | |
| Ceratites | | | | | | | | ■ | | | | |
| Ammonites | | | | | | | | ■ | ■ | ■ | | |
| Nautiloids | | | | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ |
| Orthocones | | ■ | ■ | ■ | ■ | ■ | ■ | ■ | | | | |
| Belemnites | | | | | | | | | ■ | ■ | | |
| Teuthids (squids) | | | | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ |
| Octopods (octopus) | | | | | | | | | ■ | ■ | ■ | ■ |

Answers to Data Analysis Questions:

1. Triassic
2. Mississippian or Pennsylvanian
3. Triassic
4. Ordovician to Triassic
5. Ammonites, Nautiloids, Belemnites, Teuthids, Octopods
6. It is impossible to tell because the absence of ammonites might only mean that no ammonite happened to fall in that particular piece of rock or it might mean that the rock came from a time period when no cephalopods existed.
7. Ceratites
8. A. Mississippian to Permian B. Triassic C. Jurassic to Recent D. Triassic
9. Rock C would be the best rock to hunt for oil in since it is the only one that spanned the Cretaceous Period.


**Watch the AVG Video Segment: Iowa's Diverse Fossils**
Start at 'As the DesMoines flows in its southeasterly course…'and stop after hearing 'Iowa was much closer to the equator'

**Discussion Questions**

- What was the environment like in a coal swamp?
- In what way is coal formation different from oil formation? Similar? (see student handout for a brief description of oil formation).
- Would the fossil range chart you made today be useful in dating coal deposits?
- Could a fossil range chart be useful in dating coal deposits? What would it include?

# Student Directions

**Introduction**

One of the most economically valuable uses of fossils is for finding oil. Oil companies are interested in the age of rocks because oil was produced during certain time periods on Earth. One of the most prolific periods of oil production was during the **Cretaceous**. During this time, marine algae died and built up in great quantities on the seafloor. When this organic material is buried, it is heated and put under pressure. If this continues to the right temperature and pressure, then oil is produced. The Persian Gulf region is rich in oil because it contains large quantities of rock from this time period.

Dating a rock using fossils is called **relative dating**. This is because the rocks are dated relative to each other. For instance, if one rock has a fossil T. rex and another has a fossil Saber Tooth Tiger, the one with the Saber Tooth Tiger is younger because we know that dinosaurs went extinct before large mammals appeared on earth. However, without more advanced technology, namely radioactive dating, we can't figure out exactly how old the T. Rex or the Saber Tooth Tiger are.

Ammonites are organisms that lived in the oceans at the same time as the dinosaurs roamed on Earth. They also went extinct with the extinction of the dinosaurs, at the end of the Cretaceous Period. They were very abundant, evolved rapidly, and are easily identifiable. Therefore, they are very useful to geologists who try to identify the age of rock units.

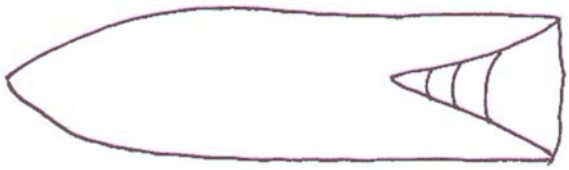
In this activity, you will create a fossil range chart for ammonites and their relatives in the Class Cephalapoda, which includes modern species such as octopuses, squids, cuttlefish, and nautilus. You will then use the information in the chart to determine the age of particular rocks and to predict which rock might contain oil.

**Procedure**

Make a fossil range chart. Look at the pictures of fossils in figure 1. Each fossil represents an order that contains a variety of genera and species. Underneath each picture is a time range. You will make a bar graph on the sheet provided. Shade in the area that represents the time period during which the fossil existed. For instance, for the Goniatites, shade in everything from the Carboniferous to the Permian (including the Carboniferous and the Permian). When this is complete, you will have made a fossil range chart.

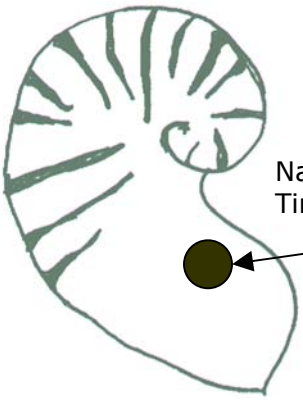
Figure 1: Representative Fossils from the Order Cephalopoda and their Geologic ranges.

Name: Ammonite
Time Range: Jurassic to Cretaceous



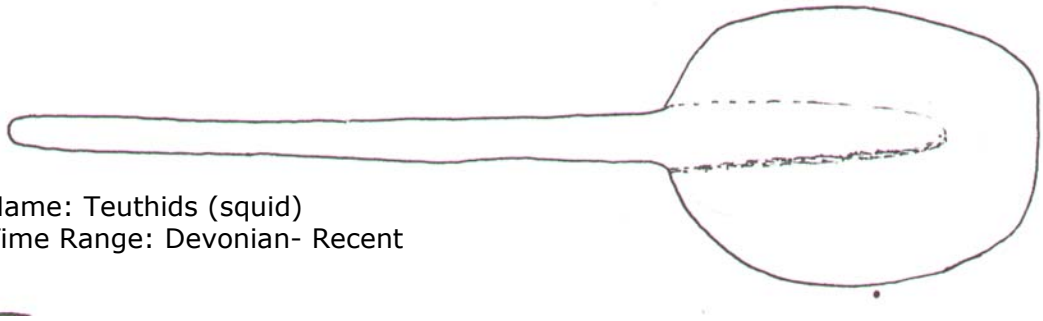
Name: Belemnite
Time Range: Jurassic to Creataceous

Name: Ceratites
Time Range: Triassic



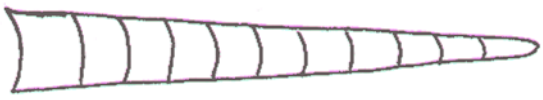
Name: Octopods (evidence)
Time Range: Jurassic - Recent

Name: Nautiloids
Time Range: Devonian-Recent



Name: Teuthids (squid)
Time Range: Devonian- Recent

Name: Orthocone
Time Range: Ordovician-



Name: Goniatite
Time Range: Mississippian- Pennsylvanian

| Cephalopod Order | Cambrian | Ordovician | Silurian | Devonian | Mississippian | Pennsylvanian | Permain | Triassic | Jurassic | Cretaceous | Tertiary | Quaternary |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Goniatites | | | | | | | | | | | | |
| Ceratites | | | | | | | | | | | | |
| Ammonites | | | | | | | | | | | | |
| Nautiloids | | | | | | | | | | | | |
| Orthocones | | | | | | | | | | | | |
| Belemnites | | | | | | | | | | | | |
| Teuthids (squids) | | | | | | | | | | | | |
| Octopods (octopus) | | | | | | | | | | | | |

**Data Analysis**

1. If you have a rock that has a Ceratite in it what time period(s) is it from? How do you know?
2. If you have a rock that has a Goniatite and a Nautiloid what time period(s) is it from? How do you know?
3. If you have a rock that has an Ammonite and an Orthocone in it, what time period(s) is it from? How do you know?
4. If you find a rock that has an Orthocone what time period(s) is it from? How do you know?
5. Which fossils might you expect to find in a rock of Jurassic age?
6. If you find a sedimentary rock that has no Cephalopods in it, can you tell what time period it is from (using the information available in this lab only)? Why or why not?
7. Which fossil(s) make the best index fossils?

**Application**

8. Look at the following diagrams of fossils that can be found in rocks. Identify the fossils using the pictures in figure 1. Then determine the age of each rock.
9. Cephalopods are organisms that lived in the open ocean. During the Cretaceous, a lack of oxygen in ocean basins meant that large deposits of organic material built up. This material came primarily from microorganisms in the ocean water. This material was later buried and eventually became oil. Geologists from oil companies frequently use range charts to help them date rocks so that they might find more oil.

   Imagine that you are an oil geologist. Of the rocks you dated in question 8, which would you recommend further investigation for oil?

**A**

**B**

**C**

**D**